DOCUMENT RESUME

ED 282 067 CE 047 288

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TITLE The Skill and Training Implications of New Technologies: Some Issues. Training Policies Discussion Paper No. 10.
INSTITUTION International Labour Office, Geneva (Switzerland).
REPORT NO ISBN-92-2-105138-2
PUB DATE May 85
NOTE 34p.; Appendixes contain small type.
PUB TYPE Viewpoints (120)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Career Education; Developed Nations; *Developing Nations; *Educational Change; Foreign Countries; Job Development; *Job Skills; *Job Training; Labor Force Development; Labor Market; *Labor Needs; *Technological Advancement

ABSTRACT

In contrast to high technologies generally developed in the industrialized countries, technological development in the new industrial countries is mostly characterized by innovative efforts to change imported technologies over a period of time. Economic and social impacts of the introduction of new technologies include the significant reduction of work phases in the production cycle; significant reduction in the labor force needed for producing a given level of output; improved quality of life benefitting both the producers and consumers of goods and services; changes in the distribution of employment between sectors; change in job structure and content; and changed skill and knowledge requirements of the labor force. The new technologies may have a significant impact on how the work and production processes are organized and on the content of individual job and work tasks. These changes at the workplace have significant implications for the skills and qualifications profile of various categories of the labor force, from top management personnel to skilled workers. Technological change implies changes in enrollment policy as well as in training policy as regards training content and the structure of the training delivery system. (YLB)

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TRAINING POLICIES

Discussion Paper No. 10

THE SKILL AND TRAINING IMPLICATIONS OF NEW TECHNOLOGIES: SOME ISSUES

by

Torkel Alfthan

Note: Discussion papers are preliminary material circulated to stimulate critical discussion and critical comment.

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May 1985

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ISBN 92-2-105138-2

First published 1985

Second impression 1986

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Printed by the International Labour Office, Geneva, Switzerland

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The Skill and Training Implications of New Technologies: Some Issues

Introduction

The economic and social impact of new technologies on training and education is the subject of a debate in the industrialised countries today, as well as in some of the more advanced developing countries.

Since the early 1970s, changes in the locations of industry as they launch themselves into modern economic and social life throughout the world, and in the relative cost of production and technology have interrelated to cause a structural transformation of the world economy. There has been a decline in manufacturing as such in the old "mature" industrialised countries while a rapid expansion has taken place in the new industrial countries ("NICs") notably Brazil, the Republic of Korea, India, Singapore, Taiwan and Yugoslavia.

Technological change plays an important role in the shifts of emphasis between industrial sectors. The "old" industrialised countries face increasing competition from the NICs, not only in textiles and foodstuffs, but also in chemicals, metals, vehicles and capital goods production. They are gradually - and often with considerable pain - moving away from goods production towards providing information-intensive services, a development which is greatly accelerated by the relatively reduced costs of information processing. At the same time, some of the NICs are making inroads in advanced technological manufacturing based on high value added production and the use of an increasingly educated and well-trained labour force.

The sectoral - or structural - shift in the production of goods and services, combined with the development of new equipment, new production techniques and new products (i.e. technological change proper) affect the number of jobs available. It can also modify job content, as well as the skills and qualifications required at the workplace and hence training policy formulation and the design of education and training programmes. The

implications of these developments in new industrial countries are the main topic of this paper. The main focus of the paper will be on new technology in the manufacturing sector. However, before proceeding, it may be opportune to dwell briefly on the nature and contents of new technologies, as these may have some significance for the necessary response of training and education systems and programmes to adjust to changing requirements for skills and qualifications.

1. "New" technologies: some definitions

The production process can be defined as a combination of inputs, work organisation and outputs. Technological change[1] or innovation may affect any part of this process to make it more cost-effective, to save labour, capital or raw materials. It may take the form of changing raw material inputs or the means of production, e.g. machines or equipment, by reorganising the work process or by modifying the form or composition of output, primarily by introducing new products or services or even by simply changing the factor proportions, i.e. the relative shares of labour and capital utilised in the production process.[2] In this way, innovation can be defined as the development of "new" technologies, e.g. new products and processes, which in varying degrees incorporate findings of research and development efforts. Thus, new technology is a concept covering a broad spectrum of technologies ranging from "emerging", "frontier", "advanced" and "high" technologies (these are synonymous concepts) which incorporate the latest findings of science and research and development to what has been called "minor" innovations[3] involving changes in imported technologies to suit particular local conditions. For the purposes of this paper, we are concerned with innovations that are - or are expected to be - widely applied and diffused in economic and social life.

High technologies include first of all micro-electronic applications involving information storage, transmission and manipulation. Micro-electronic devices are incorporated in products or processes ranging from consumer goods (household appliances, TVs, videos, cars, cameras, watches etc.) to computers, telecommunications equipment, industrial control equipment and systems, robots, banking and insurance operations, test, measuring and

analytical instruments, office equipment, military, aerospace and marine applications. Another area is biotechnology which is used in the production of pharmaceuticals, chemicals and vaccines, in food processing and in plant and animal agriculture. Yet another field is the entirely new range of materials that are being created by engineering technologies, inorganic chemistry and other supporting disciplines. Examples are fibre reinforced composites (e.g. carbon fibres, short metal fibres), fine ceramics and high strength low alloy steel. Last, but not least in the field of high technology applications, are those technologies using satellites and remote-sensing techniques for observation, inventory and analysis of natural resources, whereas another group refers to applications of photo voltaic cells for converting sunlight directly into electricity for use as a power source. The annexes give examples of economic applications of micro-processors (Annex A), biotechnology, genetic engineering (Annex B) and new materials (Annex C).

In contrast to these high technologies, generally developed in the industrialised countries, technological development in the new industrial countries is mostly characterised by innovative efforts to change imported technologies over a period of time. There is a very active process of "minor" innovation or development of adapted technologies that have been imported from the more industrialised countries, but have been modified to suit local conditions, for example in terms of cost efficiency, availability of skilled manpower, and favouring the use of local raw materials.[4] At the plant level, these innovations may occur in quality control, plant layout, equipment modification and product adaptation and at higher levels in product and process design facilities, pilot plants, laboratories and in independent science and technology facilities.[5] The development of the latter, also challenges training and education systems. With increasing technological sophistication they demand, arguably, higher skills and managerial abilities and tend, over a period of time, to change the occupational and qualificational distribution of the workforce. Many claim that the major factor in enhancing technological capability within an enterprise is an internal learning process through which - combined with education and training - production experience yields information and stimuli which prompt improvement.[6]

2. The economic and social impact of new technologies

2.1 Impact of new technologies on systems of industrial production

A well known phenomenon caused by the introduction of new technologies, in particular micro-electronics, is the significant reduction of work phases in the production cycle. The cycle can be summarised as a succession of transformation phases in which parts and components are made from raw materials, and sub-systems and end products from assembled parts. This process is being radically changed with the application of LSI (large-scale integration) components and the prospect of even greater developments in VLSI (very large scale integration), which make it possible to build a growing number of previously assembled parts and systems into the components.

Growing component integration, accompanied by a marked reduction in costs for parts and elementary functions, has resulted in shifts of manufacturing activities and value added from end product enterprises to companies producing micro-electronic and other new technology components. Also, the substitution of parts and sub-assemblies with micro-electronic components, for example the replacement of labour-intensive production of mechanical and electro-mechanical telephone equipment with integrated electronic telephones produced with automated equipment, has led to reductions in value added, and, in particular, the labour content of production. The manpower needed for producing a given level of output is therefore significantly reduced, with potentially important implications for the quantity and quality of employment available.

2.2 Potential social and economic benefits of new technologies

New technologies have the potential to greatly improve the quality of life by benefiting both the producers and consumers of goods and services. The producer may enjoy a cleaner, qualitatively superior and more participative working environment, improved productivity and therefore higher income and a higher standard of living. The consumer can also reap substantial benefits from new technologies as products and services become cheaper and are qualitatively improved. On the other hand, new technologies may also have detrimental effects on welfare, other than employment, as for example may happen when the consumption of essential low income goods or services are

substituted by new technologically advanced, often high income goods or services, resulting in insufficient expenditure on basic needs, goods and services.[7]

To maximise the positive consequences of new technologies, their benefits in terms of improved quality of work, higher incomes and better products, have to be equitably distributed between capital and labour and between various categories of labour and population groups. Education and training have an important role to play in equipping the worker with the knowledge, skills and qualifications necessary for maximising his or her share in the value-added generated by the new technologies.

2.3 Impact on the labour market

The introduction of new technologies has an important, often profound, impact on the labour market. Firstly, technological change significantly changes the distribution of employment between sectors, industries and individual firms leading, in some areas, to job losses and in others to job gains. It is still widely debated whether the net effect of technological change is labour displacing or labour absorbing or whether the effect is neutral.[8] The effect on employment, which can be attributed to technological change per se, is difficult to evaluate as other causal factors also influence the volume of employment, such as the increase or decrease in the demand for the firm's products, reorganisation of the work process and the opening up of completely new lines of production. The literature dealing with this issue is abundant[9] and it will therefore not be dealt with further in this paper.

Secondly, the structure and contents of jobs emerging from the process of technological innovation are constantly changing as new jobs are created, some are modified and others disappear. A fundamental factor determining job structure and content in the wake of new technologies is the nature of the technology itself, but often the management policies regarding the uses to which the technology is put and the organisation of the work process, as well as the skill and qualitative profile of available manpower is equally important. In fact, often the same output can be produced with widely differing proportions of labour and capital and with different structures of manpower, occupations and skill profiles. The argument for absolute technological determinism is therefore weak.

Thirdly, and closely associated with the effects of new technologies on work organisation and job structure and content are their impact on the skill and knowledge requirements of already employed manpower and/or additional manpower demanded. Again, the type and levels of skill and qualification required will largely depend on what type of work organisation and job and task structure is opted for as well as on the technical requirements of the technology itself.

Fourthly, new technologies have an important impact on the training and education system as companies and education and training institutions, with varying success, try to adjust to changes in the structure of employment, job content, occupations and skill requirements. The issues mentioned in the last three paragraphs are further developed below.

3. Effects of technological change on job structure and content

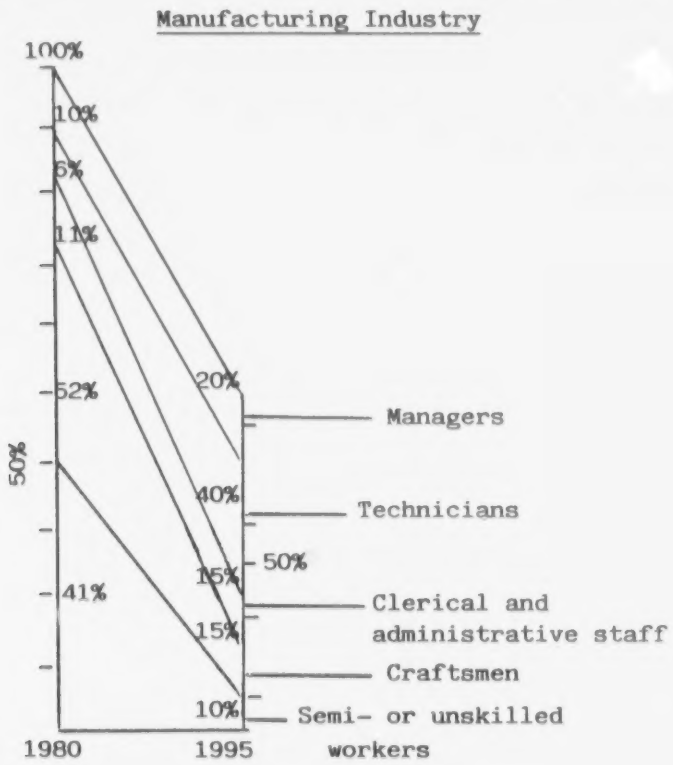
In aggregate terms, the employment structure is in a process of constant change as new technologies are introduced. To take a longer term perspective, structural and technological changes in the economy and changes in labour force participation rates, particularly among women, have significantly changed the pattern of employment from being primarily agricultural to become increasingly industrial. Today, the process in the industrialised countries is continuing as tertiary sector jobs are gaining ground at the expense of primary employment and to an even greater extent, of secondary employment. In developing countries, industry and, to a lesser extent, services have provided jobs whereas agricultural employment has declined in relative terms. These changes in economic structure have their corollary in occupational changes, yesterday from rural occupations to industrial occupations and today from blue-collar occupations in industry to white-collar jobs in industry and the tertiary sector.[10]

In the industrial enterprise, new production techniques and the manufacture of new or modified products imply changes - often radical in nature - in the organisation of productive - and "non-productive" - work and therefore in job structures, illustrating the shift at the aggregate level from blue-collar to white-collar jobs. The metal industries, for example, display a long-term trend towards a gradual change of emphasis from directly productive activities to various types of preparatory and controlling

activities and from the application of manual skills to the use of cognitive skills.[11] This is in line with the general findings of the Battelle Institute's study of the impact of the increasing use of micro-processors and micro-computers in economic activities.[12] It found that the jobs in the future can be expected to require, in relative terms, more general skills, such as abstract thinking and planning skills and ability to work in a team, than manual skills.

These changes in job content are expected to be reflected by a significant change in the occupational structure of the workforce in manufacturing industries. Figure 1 below, projects the changes in occupational structure in U.K. manufacturing between 1980 and 1995.

Fig. 1. Structure of employment in the U.K.: estimated changes 1980-95



Source: Commission des Communautés Européenes : Europe 1995 : Mutations technologiques et enjeux sociaux, Rapport FAST, Bruxelles 1983, p. 127.

Personnel in management positions and at technician levels are expected to increase their respective relative shares in the occupational structure at the expense of unskilled and semi-skilled workers and of craftsmen. These changes are anticipated to take place amidst a general absolute decline in manufacturing employment.

3.1 Determinants of job structure and contents

These trends and projections could suggest that the chosen technology itself is the major determinant of individual job structure and content. However, many people, especially in the trade unions, object to the contention that the technical characteristics of the new machinery, equipment or system are the unique factors influencing the organisation of the work process and the formation of job content. They argue that innovations in work organisation and other management practices can significantly improve the quality of jobs affected by the technology. On the other hand, management decisions regarding technology and manpower utilisation also have the potential of making work more monotonous, fragmented and qualitatively inferior.

The direction of change in job structures and their qualitative content therefore depend on a number of technical, economical and social factors as well as on the relative bargaining power - and philosophy - of management and workers or their representatives, in the process of technological change. The following can be said to constitute factors most conducive to improvement in work organisation and job content with the introduction of new technologies: (i) "progressive" attitudes on the part of management towards the role of human capital in meeting company objectives, (ii) active involvement by trade unions and workers, in collaboration with management, in activities emphasising innovations in technology, production systems and organisation of work and (iii) a highly trained workforce which, precisely because it is highly trained, can adjust to changing technology and can therefore effectively challenge any tendencies to make work more fragmented, more monotonous and de-skilled. High labour force quality, i.e. high educational standards and qualifications, are therefore among the best guarantees against dequalification, de-skilling and other negative tendencies at the workplace.

3.2 Reorganisation of work: a concrete example

A concrete example from Alfa Romeo di Arese in Milan supports the claim that the new technology does not simplistically determine the structure and content of jobs in the company but that innovations in work organisation and other management practices can enhance the quality and skill content of the jobs affected by the technology. It also illustrates the decisive contribution made by workers and trade unions in finding innovative solutions to problems of productivity improvement, work reorganisation and training. In this case, the application of new technologies has turned into an opportunity to achieve a greater degree of industrial democracy.

Forced by competitive pressures to increase plant productivity, management and the trade union at Alfa Romeo worked in close collaboration to undertake a substantial reorganisation of the car manufacturing process. Faced with the "alternative of simply replacing workers by robots while retaining the traditional pattern of work organisation or completely transforming the production and qualification systems", Alfa Romeo decided in favour of the latter.[13] This decision was largely prompted by the attitude and insistence of workers who, with time, had come to expect a better quality of work rather than be content with "raising and lowering steel plates for the rest of their lives and breathing in polyvinyl chloride contained in the varnish, which may cause cancer".

The reorganisation of the work process has meant that individual production, rigidity of assigned work tasks and simple jobs have been replaced by group work, alternation of workplaces and complex jobs. New occupations have been introduced, e.g. thermal processing specialists and automated varnishing specialists, which are "indicative of a gradual and vertical integration of work and a shift towards occupations geared to processes rather than specific skills: regulation of parameters, quality control, minor maintenance, financial management etc."[14]

4. Impact of new technologies on skills and qualifications

The previous section noted that new technologies may have a significant impact on how the work and production processes are organised and on the content of individual job and work tasks. These changes at the workplace have

significant implications for the skills and qualifications profile of various categories of manpower, from top management personnel to skilled workers.

Again, the changes in skill, knowledge and qualification requirements in the process of technological change do not operate in any single direction. New processes or systems of production and new products may mean higher skill and/or knowledge requirements in certain jobs, lesser skills in other jobs and unchanged skills in still another category of jobs. The major determinants of the direction in which skills and knowledge requirements change are the same as those enumerated in the discussion of changes in work organisation and job content on pages 6 - 8.

4.1 Impact on higher level skills and qualifications

The U.K. projections of the expected occupational structure (diagram on page 7) suggested a greater relative share of highly qualified personnel. In addition, it has been claimed that the development and introduction of new technologies demand a diversity of specialists who need to work together and who can "accommodate complete systems for which the basic ingredients of financial, physical and human capital need to be supplemented by the more subtle and intricate ability of integrating them into a meaningful whole".[15]

However, the trends are not always as clear and unequivocal as the above text would suggest. It should be remembered that changes in manpower structure resulting from technological change generally mirror both the demand for and supply of particular skills and qualifications. A British study of the electronic components industry - no stranger to new technology - found that in 1977 it employed a higher proportion of skilled craftsmen to produce a given output than was the case in 1970, while it employed a lower proportion of technicians.[16]

In the same period, the proportions of scientists and technologists in the machine tool industry also fell, while the share of technicians actually increased. One plausible reason for these changes in manpower structure could be that the short and inelastic supply of engineers, scientists and highly skilled technicians have induced employers to adjust their production, work

organisation and utilisation of manpower to the existing availability of skills and qualifications in the internal and external labour markets. A supplementary reason may be that the quality or the skills, qualifications and experiential profiles of engineers and other advanced technical personnel presently coming out on the labour market are inadequate to meet employers' needs. The FAST report[17] on the social implication of technological changes in Europe, published by the European Commission, observes that European universities, compared with American and Japanese higher education institutions, are unable to "produce" a sufficient number of engineers to satisfy the growing demand by firms manufacturing semi-conductors and that their education and training is too academic and not sufficiently business oriented, as they lack links to, or bridges with, industrial firms.

4.2 Managing technological change

A manpower category expected to assume a more prominent role - both quantitatively and qualitatively - in the industrial firm in the future is the managerial group. This development springs in no small part from the initiatives - albeit often cautious - of many governments today to end subsidisation of industries and to deregulate prices and other variables in the business environment in order to stimulate entrepreneurship, innovation, competition and an international orientation of industry.

A less controlled business environment can be expected to put out new challenges to industrial managers, as the past, relatively surprise-free, business environment is gradually replaced by an as yet uncertain and unpredictable future. In the final analysis, the success of any particular national economy depends upon the productivity of its human resources and on the ability of domestic firms to market a product internationally and/or to remain competitive in the face of foreign imports. Know-how, which is the basis for innovating and for adding value, represents an operational definition of productivity.

Productivity, in turn, derives from the ways in which specialists can work together effectively, by means of innovative management of human resources. The onus is increasingly on a complex assemblage of people in a variety of positions and roles to somehow work together, cutting across all the corporate functions and compartments.[18]

The following skills are expected to figure prominently in the profile of the manager responsible for technological change:

- ability to use computers as management tools;
- ability to recruit people having strong theoretical underpinnings with applied expertise in the company core technology so that the recruit can make an intermediate productive contribution; recruitment is done by the manager himself;
- organisational and motivational skills to establish, organise and motivate teams of people working on the basis of face-to-face communication, frequent and prompt feedback on performance and clear and total responsibility, cutting across all functions from conceptualisation to marketing and beyond.[19]

As a primary characteristic of the innovating firm is impermanence, it appears to be extremely difficult to plan the training of managers managing technological change. "Managers will relate with people in ways we do not know and cannot teach".[20] Many skills will therefore have to be learnt on-the-job as managers are developed who can work with the new breed of "knowledge" workers essential for company success.

4.3. Technological changes and skill and training requirements of technicians

It was forecast that technicians would assume a central role in the industrial manpower structure in the foreseeable future. Fig. 1 on page 7 depicts the quantitative implications of changes in the labour force structure with the technician's share expected to increase most significantly compared with the other categories. By 1995, technicians are likely to take up more than a third of industrial jobs in the U.K.

This quantitative expansion is expected to go hand in hand with a qualitative strengthening of technician training. According to a Danish report[21] on the subject, mechanisation/automation of production during the past decades has steadily replaced manual work tasks and jobs with supervisory and control functions. In the future, this trend can be expected to continue as production design, quality control, repair functions, etc., are increasingly taken over by automatic functions. This will mean a continued shift away from manual technician functions to functions where "software" skills and qualifications will be required.

Technician training will, therefore, increasingly need to incorporate training in computer-aided design (CAD), computer-aided manufacturing (CAM), data communication techniques, and production control and steering based on electronic data processing techniques. Many observers[22] argue that the training must be broadly based - also incorporating such subjects as mathematics and foreign languages - the rationale being that a broader technical experience base allows technicians - as well as other high level personnel - to contribute a wide variety of possible applications of new technologies.

4.4 Impact of technological change on the skill requirements of skilled workers

The projection of the manpower structure up to 1995, suggested a secular decline in the relative shares of craftsmen and semi- and unskilled labour and a proportionate increase of technicians and management personnel in the manufacturing sector. If this projection proves correct, it implies a general upgrading or qualitative improvement of the industrial labour force. These forecasts are supported by empirical studies that contain little evidence to support the belief that new production technologies are going to bring about a general shift into semi-skilled manual work.[23]

A relative increase of semi-skilled labour in industry would confirm the thesis advocated by Braverman[24] that, as a result of market pressures and capital labour conflict, technological change has an inherent tendency to downgrade craft skills and increase management's control of production. As the Alfa Romeo case referred to earlier already illustrated, one reason that the downgrading tendency is more the exception than the rule is that management policies, rather than technology per se constitute the primary influence on the innovation process and its consequences, including skill implications. A practical case from British Leyland's new Longbridge factory highlights how management's policies have in fact - with minor exceptions - upgraded the skills of maintenance workers, although they had a significant effect on tradesmen's cherished job rights. The case also illustrates some aspects of the dynamics of industrial relations in the factory.[25]

4.4.1 Impact of new technologies on maintenance workers' skills and working practices: the Longbridge case study

For the production of the Mini Metro car, in what was called the BIW (Body in White) production process, a new factory was established, housing a vast array of new technologies, including industrial robots. The BIW process was highly automated, involving a high degree of process integration and production continuity. High efficiency objectives for the new factory - for instance an 85 per cent level of machine utilisation - created a very high level of demand in the maintenance area. The whole process of design became dependant upon the speedy and effective performance of the maintenance task. However, while the introduction of the new technology had put the maintenance workforce in a powerful position, production efficiency depended on management's ability to achieve radical changes in the skills, work practices and work organisation.

The Longbridge management opted for (a) two trade maintenance - electrical and mechanical - instead of the five different trades currently involved in maintenance and repair; this was expected to produce gains in terms of speed of response and maintenance productivity, (b) on-line maintenance under which tradesmen would no longer be based in a central off-line pen in each workshop but on-line and thereby able to deal more quickly with problems, responding directly to machine breakdowns rather than requests from production foremen channelled via their supervisor, (c) supervision based on the response of maintenance workers to the commands of production supervisors when engaged in on-line duties.

Failing to achieve these objectives of change by means of negotiation, management pursued, and succeeded by and large, in a policy of piecemeal erosion and redefinition of the existing maintenance organisation.[26] Under the new arrangements emerging from this process, a machine could be serviced by a two trade team made up of machine tool fitters and electricians, although each worker could continue to regard himself as a pipefitter, millwright, etc. However in theory, although their trade demarcations remained, in practise they lacked relevance. In fact, this reorganisation on the basis of a two-trade allocation of work tasks, implied an actual upgrading of skills, in many cases, although some marginal deskilling also took place with the expropriation of tasks such as tip-changing, electrode dressing and weld setting, to a newly formed semi-skilled grade called "weld setters".

The electronic technologies in the BIW process also created a significant need for new programming and computing skills in the maintenance area. As these were considered to be mainly of the abstract and mental skills variety which are not generally considered part of manually based capabilities and expertise, management was able to appropriate them for a new managerial function, which was given the title "control engineering". This new function impinged upon the tradesmen's traditional autonomy as the newly created "control engineers'" role included "co-ordination" of the tradesmen on a number of tasks and a controlling role in the maintenance of the most sophisticated production systems.

As a conclusion, it can be said that although maintenance workers' skills were probably enhanced in the new factory, "an essentially hierarchical structure was developed in the maintenance area with staff graded control engineers at its apex and embodying a Taylorist tendency towards the separation of mental and manual skills."[27] The maintenance workers' strategic power was "effectively incorporated within a more broadly defined maintenance function, whose parameters were now established not by trade demarcations, but by management objectives."[28]

4.4.2 Technology agreements

Another reason why the deskilling model is not necessarily found in a real shopfloor situation today may be that organised labour, with the backing of its bargaining position as well as certain progressive employers, have drawn attention to the risk of deskilling and have strongly advocated the signing of agreements between labour market partners that provide safeguards against downgrading of skills and adequate opportunities for retraining or upgrading when new technologies are introduced. In many countries, the negotiations on such agreements have become part of the regular collective bargaining process between labour market partners.

The Association of Professional, Executive, Clerical and Computer Staff (APEX) has pioneered the negotiation of such agreements with employers in a range of industries in the U.K. A review of these agreements[29] found that the majority of them include a guarantee that no employee will be down-graded and that revised jobs are referred to a joint (employer/worker) job evaluation machinery. Some agreements allow redeployment to a lower grade although the individual is guaranteed the same salary grade and increments as in his former

position. They often have clauses aimed at minimising routine and monotony in jobs and most agreements include more or less detailed references to training in order to maintain or raise skill levels.

4.4.3 Manual skills versus cognitive and theoretical skills of workers

Page 6 and 7 referred to studies predicting that the workforce of the future, including skilled workers, will need a skill profile where systems-related, cognitive and abstract thinking skills will have an important place. This was considered to result from the application of a systems approach to the solving of manufacturing problems.

Other observers contend that tomorrow's industrial firms will have a decentralised, diversified pattern of production which has the capacity to quickly adjust to specific customer needs for goods and services of specific quality. This pattern, it is argued, is more conducive to small-scale production and it is symptomatic that small enterprises are presently mushrooming. There is also evidence to show that small enterprises, in both developed[30] and developing countries[31] have a better record of product development and innovation than larger companies. It is therefore claimed that if the production of goods and services increasingly takes place in such production units, job-oriented skills of workers become even more important. Diversified, practical skills in turn stem from good quality vocational training, in each case carefully tailored to the manifold job tasks of specific occupational groups[32].

5. Training and education implications of technological changes

Changes in skills and knowledge as well as in attitudinal requirements induced by technological changes have a significant impact on the formulation of training policies and the design and implementation of education and training programmes, be they in schools, higher educational institutions, specialised training institutions, in apprenticeship schemes or in other enterprise-based training.

By training policy, we mean the objectives of training and a plan of action to meet these objectives. Training policy defines what should be

achieved and how it should be done and consists of elements such as training policy objectives, planning of training, the structure of the training delivery system and the financing of and incentives for training[33]. Innovations in products and production processes, in work organisation and in manpower utilisation can all be expected to have an impact on the various elements of training policy. These impacts are discussed systematically below: we start with policies of enrolment for education and training courses and programmes.

5.1 Enrolment policy implications

First of all, technological change implies quantitative changes in the composite demand for various categories of manpower, say in increasing the demand for engineers and technicians and decreasing the demand for craftsmen and semi-skilled and unskilled labour. These changes, in turn have a direct impact on policies of enrolment, provided that the information from the labour market about manpower demand is adequately fed back to and made use of by the authorities or institutions responsible for enrolment policy. The impact may be felt in shifts in the relative proportions of trainees enrolled in various training and educational disciplines (say a shift from mechanical to electronic engineering) or in enrolment for training at various levels of skill and qualification (say more emphasis on technician training than on craftsman and skilled worker training).

Technological change may also influence enrolment policy in terms of the desired profile of enrollees in various schemes and courses of education and training. Changes in the expected, or hoped for, skill and qualifications profile of the training graduate may imply that admission requirements to training courses and institutions need to be changed. For example, more emphasis may be put on enrolling students with a good background in mathematics and computing, or students with job experience in certain competency areas or in the disciplines of the particular training programme. Alternatively, admission requirements may need to be changed to favour students with, say, particular academic, psychomotorial or other educational or skill qualifications, or students with specific attitudinal characteristics.

5.2 Training policy implications

5.2.1 Contents of training

Changes in skill and qualification requirements in the wake of technological innovation necessarily imply that the content of training, or the training curriculum (i.e. what is being taught) need to be changed. For example, from the employer's point of view, they may imply underlining cognitive, abstract thinking skills at the expense of practical, manual skills or changing the relative emphasis on various technical disciplines preparing for a particular occupation or job, i.e. by putting more stress on computer-related knowledge and skills while de-emphasising, say, mechanical engineering skills. Alternatively, they may imply minor, and some argue easily managed, additions or appendices to existing curricula as may happen when certain computer-related skills are added to existing training curricula for operatives or skilled workers.

From the public point of view, however, it is widely argued that education and training must not be exclusively determined by employer's needs for specialist knowledge and skills, but that "civic knowledge and skills" should also be taught, in order to facilitate understanding and the social assimilation of new technologies.

Flexibility is a key word when discussing production systems employing new technologies. Flexibility implies potentially rapid increases in product diversity and an ability to quickly change the composition of output to satisfy specific customs needs. This in turn may demand swift modification of the working schedule, manpower utilisation, workers' skills and qualification profiles to meet production requirements.

Flexibility must therefore be an essential feature of future training systems. This means that the end result of training, i.e the acquisition of a particular skill or qualification can be achieved by different and more important, by commonly accepted means, modes, and methods as well as durations and sequencing of training. To take an example, the acquisition of engineering qualifications should, in the future, be possible by either starting the career path with working practice or with theoretical education and training, followed by complementary upgrading training and/or practical work. Under such a flexible career development system, any worker will have

the opportunity to pursue his career goals and be given the chance of upgrading or changing his skills and qualifications in the face of technological change, irrespective of his present educational and employment status.

5.2.2 Impact of technological changes on the structure of the training delivery system

As requirements for skills and qualifications undergo changes caused by innovations in product and production processes and by new approaches in the organisation of work, the relative importance of the various schools, institutions, schemes and opportunities for education and training can be expected - at least in the long run - to undergo substantial modifications. Similarly, the relative increase in the manpower structure of particular categories. (e.g. technicians and managers, at the expense of other categories), can be expected to have serious repercussions on the structure of the training delivery system.

If the skills required are significantly different from their predecessors and demand a different pattern of training delivery, the changes are likely to favour or give a comparative advantage to certain institutional types or modes of education and training at the expense of others. For example, if a future job profile emphasises cognitive skills and abilities of analytical and abstract thinking, it could be argued that institution- and classroom-based education/training would have a pedagogical and cost advantage compared with, say, enterprise- and apprenticeship-based training programmes. The reverse situation would prevail if the development of manual, practical skills and qualifications are emphasised.

However, the education and training system may not always respond as smoothly and efficiently to market forces as the above may suggest. Different countries tend to adapt their training systems to changed skill requirements in different ways by integrating - not necessarily in an optimal fashion - training for new technology into nationally specific courses and patterns of training, thus leaving the particular characteristics of the national training system intact.[34] For example, in countries with a strong apprenticeship tradition, the appropriate training response to new technology may be to

gradually change apprenticeship courses by adding computer operator and other applications of micro-electronics to existing courses or arranging for training in CNC operation and programming by manufacturers of CNC machines. On the other hand, countries that have no apprenticeship tradition may instead opt for strengthening the capacity of existing formal education and training institutions and centres to incorporate elements of training for new technology into their existing curricula.

If the pace of technological innovation is presently accelerating - with continuous changes in job profiles and skills, education and training requirements - a comparative advantage will accrue to those training and educational institutions that closely collaborate with industrial firms in such areas as identification of training needs, joint elaboration of training plans and curricula.[35] In some countries, e.g. Singapore, the policy has been to promote joint government-private sector training centres by soliciting the co-operation of foreign firms engaged in manufacturing high technology products and incorporating high technology processes. The centres combine off-the-job and institutional training with practice in simulated work environments and in the factory.[36]

The need for flexibility in the content, method, duration and sequencing of training mentioned above also has its necessary parallel in the need to modify the structure of the training delivery system. It can be expected to become more fluid and changeable (flexible) as courses, schemes, institutions, are put up, modified or abolished in response to changes in demand for various skills and qualifications. However, this does not lessen the need for good quality basic vocational training that enables trainees to benefit from shorter term upgrading and retraining courses.

5.2.3 Corporate education and training

In some advanced countries, in particular the United States, the structure of the training and education system is undergoing significant, even revolutionary changes with the arrival of new technologies at the workplace. Today, it is estimated that nearly eight million people in the US, which is almost equal to the total enrolment in the country's four year colleges and universities, are undergoing training and education in institutions and programmes run by private corporations.

This is in response to galloping technological development which can render an engineer's training obsolete in five years and the tendency of universities and other educational institutions proper to lag one to three years behind what is happening at the workplace.[37] Close affinity with actual job practises, clear definition of training objectives and immediate application at the workplace of curricula taught have rendered these corporate institutions and programmes highly effective.

Finally, lower costs of manipulating and retrieving computer-based information could, in the future, remove the constraints of prevalent modes of training and education in institutions and make it possible to provide all people, on a continuing basis, with the basic ability to use and benefit from information technologies. Such skill development could take place anywhere, even at home. In this vein, it could be argued that the aim of social, educational and cultural policies should be to create a social climate where the new technology permeates the entire cultural fabric of society.

Conclusions

Whether they are wanted or not, new technologies are inescapably becoming an integral part of economic and social life everywhere. Even the new industrial countries are being forced to meet the old industrial countries' challenge to recoup the manufacturing activities which were lost in the 1970s, through the use of such new technologies as robots and information-intensive micro-electronic control equipment..

Upgrading education and training systems and programmes, will be significant elements in meeting this challenge as the emerging manufacturing systems will require a more highly qualified labour force than the older, traditional technologies. Some countries, e.g. Singapore, have already developed innovative training policy instruments to meet these requirements by, among other things, taxing the employment of low-skilled or low-wage labour in a determined effort to develop its human resources and advanced technology industries.[38]

This paper attempts to identify those issues and problem related to the skills, qualifications and training requirements generated by technological change, and to formulate some hypotheses about the necessary policy responses

necessary to meet them. A subsequent publication will test these hypotheses with the use of empirical data obtained from case studies in selected new industrial countries.

Notes

1. Technological change or innovation may be defined as "the introduction of new or modified products or production processes. It is the last stage in the process of (a) invention, i.e. the discovery or devising of new products and processes and (b) development, the process by which the ideas and principles thrown up at the stage of invention are embodied in concrete products and techniques of production leading to innovation. In one sense, innovation is the most important of these stages, since it is only when this stage is completed that the fruits of invention and development are gained". Quoted from G. Bannock, R.E. Baxter and R. Rees Dictionary of Economics, Penguin Books, London 1983. See also G. Standing: "The notion of technological unemployment", in International Labour Review, vol. 123, No. 2, March-April 1984.

2. S. Lall: Technological change, employment generation and multinationals: A case study of a foreign firm and a local multinational in India, Multinational Enterprises Programme, Working Paper No. 27, ILO, 1983, p. 5.

3. F. Stewart and J. James (ed.): The economics of new technology in developing countries, London, F. Pinter, 1982.

4. F. Stewart and J. James, Idem.

5. Idem. and Lall, op. cit.

6. Martin Bell, Don Scott-Kemmis and Wit Satyarakwit: "Limited learning in infant industry: A case study" in Stewart and James, op. cit.

7. For a discussion of the welfare effects of new products in developing countries, see Jeffrey James and Frances Stewart "New products : A discussion of the welfare effects of the introduction of new products in developing countries" in James & Stewart, Ibid pp. 225 - 255.

8. For an overview of the debate on the subject, see Institute of Research of Public Policy: The impacts of computer/communications on employment in Canada - an overview of current OECD debates (Montreal), Nov. 1979, 296 pp.

9. For a survey of the literature, see ILO: New Technologies: Impact on Employment and the Working Environment, (Dublin) 1984, pp. 135-174.

10. For example, census figures from Japan show that from 1970 to 1980, the increase in production and transport related jobs was only 330.000 compared with 2.350.000 sales and service jobs and 4.510.000 office, R&D and managerial jobs, a total of 6.860.000 in the latter two categories. Kimihiro Masamura: "Minimizing High Tech's Adverse Effects, in Economic Eye, June 1984, p. 28.

11. ILO: Training and Retraining of Men and Women in the Metal Trades with Special Reference to Technological Changes, Metal Trades Committee, Eleventh Session, ILO, Geneva 1983, p. 24.

12 R.V. Gisycki, U. Weiler: Microprozessoren und bildungswesen, (Munich, Vienna), R. Oldenbourg Verlag, 1980.

13. Daniela Pescarollo: "The automobile sector: technological development and vocational training", in Vocational Training, CEDEFOP, Berlin, 1981, p. 19.

14. Idem.

15. A. Bhalla, D. James and Y. Stevens (ed.): Blending of new and traditional technologies, ILO, 1984, p. 20.

16. Youthaid: Employment and Occupation Structure in Four Industries, by David Taylor (London), 1980 (Extract in ILO: New Technologies, op. cit., p. 162.

17. Commission de Communautés Européennes: Europe 1995: mutations technologiques et enjeux sociaux, Rapport FAST, Bruxelles 1983, p. 126.

18. Joseph Finkelstein and David Newman: "The third industrial revolution: A special challenge to managers", in Organisational Dynamics, Summer 1984, p. 59.

19. idem, p. 62.

20. idem., p. 64.

21. Jesper Jans: "Teknikeruddannelse og informationsteknologien", in Skolan i Norden, Nordic Council of Ministers, Copenhagen, 2.1984, p. 24.

22. For example ibid and Edward M. Knod, Jr., Jerry L. Wall, John P. Daniels, Hugh M. Shane and Theodore A. Wernimont: "Robotics: Challenge for the Human Resources Manager", in Business Horizons, March-April 1985.

23. David Taylor: See for example Youthaid: Innovation and Employment, (London) Feb. 1981.

24. H. Braverman: Labour and Monopoly Capital: The Degradation of Work in the Twentieth Century, Monthly Review Press, London 1974.

25. H. Scarborough: "Maintenance workers and new technology" in Industrial Relations Journal, Volume 15, no. 4 Winter 1985, pp. 9 - 13.

26. For further details about this policy see IBID, p. 12-13.

27. Ibid, p. 13

28. Ibid, p. 14.

29. APEX Research Department (mimeo) 1980, pp 9 (Extract in ILO: New Technologies. Idem, p. 71-72).

30. See for example: "Driving force behind growth", article in Financial Times, 12 June 1984. According to the Small Business Administration in the United States, most of the 20 million new jobs created from 1970 - 1980 were in small firms, which also accounted for two and a half times as many new products as large companies.

31. L. Kim: Technological Innovations in Korea's Capital Goods Industry: A Micro Analysis, World Employment Programme Research Working Papers WEP 2-22/WP 92, ILO, February 1982, p. 20.

32. Arndt Sorge: "New technology: what direction is vocational training taking?" in Vocational Training, CEDEFOP, Berlin, 1981.

33. For a description and analysis of training policy see M. Bermant and R. Kirszbaum: A Structured Approach to Training Policy Analysis, "Proceedings of SYNOPIS' 84, Hezeg Novi, Yugoslavia, 1984.

34. A. Sorge: Micro-electronics and vocational education and training, Discussion Paper, International Institute of Management, Berlin, June 1981.

35. Such co-operation has been very successfully developed in the United States. See for example: R. Abram, W. Ashley, C. Faddis, A. Wiant: Preparing for high technology: Programmes that work, Research and Development series NO. 229. The National Center for Research in Vocational Education, the Ohio State University, Columbus, Ohio, 1982, p. 8.

36. Singapore Economic Development Board: 1980/81 Annual Report, p. 34.

37. Time, February 11, 1985, p. 38-39.

38. Singapore Economic Development Board: 1980/81 Manual Report, p. 36.

ANNEX A. Microprocessor applications by sector

Sector	Application	Examples
Production planning		
Stock control and recording		
Quality control		
Payroll information		
Transport systems		
Energy sales networks		
Electronic thermostats		
Voltage regulators		
Heating and air-conditioning control		
Pump and compressor silencers		
Industrial control	Monitoring and data recording systems	Plant monitoring Meteorology Civil engineering Radiation monitoring
	Design	Computer aided design Computer graphics
Military, aerospace and marine	Data processing	Air traffic control systems Radar systems Navigation systems Battlefield information computers Digital cryptography coding devices Submersible acoustic navigation
	Bomb disposal	Electronic stethoscopes Explosive detectors
	Weaponry	Remote-control weapon systems Pressure guided weapons
	Communications	Direct dial portable radios Marine communications
	Design	Computer aided design Computer graphics
Transportation systems	Traffic control	Car park ticket machine Traffic flow regulator
	Servicing	Petrol pump control
	Data transmission equipment	*"Front-end" processors* *Multiplexers*
Telecommunications	Exchange equipment	Public and private telephone exchanges
	Transmission equipment	Time division Multiplex transmission Telex switching systems
	Subscriber equipment	Viewdata terminals Teletypewriters
Office equipment	Data processing	Accounting machines Visible record computers
	Word processing	Word processors Audio typing units Copiers

Sector	Application	Examples
	Audio equipment	Telephone answering machines Telephone switching systems Dictation systems
	Information transmission	Electronic mail transmission
Retail products	Sales	Cash registers Point of sale terminals Inventory Hand held terminals Stock control systems Material handling systems Weighing and measuring machines
Banking and insurance		Cash dispensers Electronic tellers Billing and accounting systems Telephone voice operated transacting equipment (see office and computer sectors)
Test, measuring and analytical instruments	Test/analytical instruments	Waveform representation machines Oscilloscopes Fracture investigation
High and low frequency fatigue cycling equipment *Tensile and compression test* *Phase-electric measuring devices* *Spectrum analyser*		
Test, measuring and analytical instruments	Medical equipment	X ray scanners Ultrasound scanners Sample analysers Electro-cardiography tests Cardiac Arrhythmias Electroencephalograph Isotope emission Tomographic scanners Cardiac output monitor Portable EKG computer Vestibular function tester Regional blood flow monitor Pulmonary function tester Microwave radiometer Electrocauterizer Audio testing aids
	Automatic test equipment	Microcircuit testers
	Nuclear equipment	Supervision of nuclear reactors
Industrial control	Sequence control	Batch processing control - petrochemicals - bulk solids Machine control - machine tools - welding machines

Sector	Application	Examples
		- high volume manufacturing systems - mail handling equipment
	Supervisory control systems and administration	Process Plant Performance achievement monitor Labour scheduling
Production planning		
Stock control and recording		
Quality control		
Payroll information		
Transport systems		
Energy sales networks		
Electronic thermostats		
Voltage regulators		
Heating and air-conditioning control		
Pump and compressor silencers		
Industrial control	Monitoring and data recording systems	Plant monitoring Meteorology Civil engineering Radiation monitoring
	Design	Computer aided design Computer graphics
Military, aerospace and marine	Data processing	Air traffic control systems Radar systems Navigation systems Battlefield information computers Digital cryptography coding devices Submersible acoustic navigation
	Bomb disposal	Electronic stethoscopes Explosive detectors
	Weaponry	Remote control weapon systems Pressure guided weapons
	Communications	Direct dial portable radios Marine communications
	Design	Computer aided design Computer graphics
Transportation systems	Traffic control	Car park ticket machine Traffic flow regulators
	Servicing	Petrol pump control
		Diagnostic systems *Wheel balancing*
	Administration	*Computerised reservations* *Automobile registration* *Fare collection equipment*
Agriculture	Cultivation and harvesting	Potato planter Operator-driven tractors

Source: Kurt Hoffman and Howard Rush: Microelectronics and clothing: the impact of technical change on a global industry. Study for the ILO, Geneva, 1983, (unpublished).

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ANNEX 8. Biotechnology market forecasts

Commercial area	*Estimated market*	*Time scale*
1 *Pharmaceuticals*		
(a) Diagnostics	US$2000 million including non-radioactive kits and monoclonal RIA kits	Already on the market. Could reach full potential by 1990. Best short-term return
(b) Drugs	US$8000 million by early 1990s, increasing thereafter according to new developments	Only one product (Humulin) on the market to date. Up-front costs and regulatory delays make this a vast but long-term field
(c) Veterinary	US$2000 million by 1990	Good short-term potential due to less stringent regulations. Market growth depends on farming economics
2 *Agriculture*	Impossible to quantify	Attractive medium-term area with worldwide potential once scientific problems overcome
Commercial area	*Estimated market*	*Time scale*
3 *Waste processing/ pollution control*	Biotech applications could reach US$2,000 million by 1990. Increased environmental concern would help	Already in use in some areas. Medium/long-term view
4 *Biotechnology Equipment and Supplies*	Currently estimated at about US$200 million per year: growth very rapid	A good short-term "backdoor" method of gaining profits from biotechnology
5 *Food and Drink*	Impossible to quantify	Human food likely to encounter consumer resistance. Fair medium-term potential for animal feedstuffs
6 *Minerals/Oils*	Has been estimated at US$4,500 million by end of century	Interesting but speculative area, dependent on economics of mineral and oil extraction
7 *Industrial Chemicals*		
(a) Enzymes	Uncertain. Dependent on economics of alternative non-biotech methods of enzyme production	Long-term view necessary
(b) Amino acids	US$3,600 million by 1990	Most promising area for biotechnology in the chemical industry
(c) Plastics	Uncertain	Unlikely to become conomically viable before end of the century
(d) Bulk chemicals	Uncertain	Outlook depends on long-term oil price prospects. Could become attractive by end of century

Source: A. Bhalla, D. James and Y. Stevens: Blending of New and Traditional Technologies, ILO, 1984, pp. 13-14. This book cites as source John Elkington: Biotechnology and employment: The integration of an emerging technology with traditional economic activities, Report for the ILO, Geneva, 1983.

ANNEX C. Some recent advances in materials technology

Material	*Technology of production*	*Properties*	*Applications*
	waste, rubber, etc.) and inorganic (slag, perlite and quartz)	lymers with inorganic fillers	
Fibre reinforced composites			
(a) Glass fibre reinforced plastic	Gas fibres used as reinforcement	Improved mechanical properties	Used in boat hulls, car body, appliances, storage tanks, and sports equipment
(b) Aramid fibre reinforcement composite	Aromatic polyamide used as reinforcement	Improved mechanical properties	Used in aircraft and marine applications
(c) Basalt fibres	Producted by drawing from a melt of rock raw material	Good insulator	Used for reinforcement of concrete, in manufacture of line pipes and insulation
(d) Carbon fibres	Produced by pyrolysis of an organic fibre	High strength and modulus of elasticity	In aircraft automobiles and sports equipment
(e) Short metal fibres	Produced from all machinable metals	Shielding to prevent electromagnetic interference, brake pads	
(f) Natural fibres	From materials such as sisal, bamboo, elephant grass	Increased mechanical (flexural, impact and tensile strength of composites)	Reinforcement for structural materials
Macro-defect free cement (MDF)	Reduction of the size of pores by kneading and grading of cement grains by polymers	High mechanical (flexural and tensile) strength	Properties of ceramics, except heat resistance, is low
High-strength, low alloy steel	Improvements in the understanding of alloying elements, microstructures of steel, mechanical properties and production processes	High-strength ductility, formability and weldability	In car industry, ship building, bridges, prefabricated buildings and pipe lines
Powder metallurgy	Rapid solidification technique	Improved mechanical properties of alloys based on aluminium nickel and steel	In car industry, ship building, bridges, prefabricated buildings and pipe lines
Shape memory alloys	"Remember" or recover their shape with a change in temperature	Heat applications	
Fine ceramics (from alumina)	Improved technology of production to eliminate cracks and air bubbles	Organic materials with properties of metals	Machine tools production, in motor vehicles engines, gas turbines, the aerospace industry and the electronics industry, electrical and optical appliances
Polyester or plastic materials	Improvements in process technology, mixing plastics with organic (agricultural	Polymers with organic fillers are lighter, do not give rise to a brittle product as po-	Wide variety of use

Source: Drawn from material in (a) E. Epremian: Some significant advances in materials technology, paper presented at UNIDO panel of experts meeting on Technical Advances and Development, Moscow, November-December, 1982; and (b) J.D. Burcell and A. Kelly: "New organic materials", in Scientific American, New Yor, May 1983; and other sources.

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